The July 24 CARB Maritime Air Quality Technical Working Group Meeting

Operation on Low Sulphur Fuel

Agenda

- Fuels of today
- Incompatibility of fuels
- Ignition and combustion characteristics
- Change-over between fuels
- Fuel viscosity
- Correlation between low sulphur fuel cylinder lube oil BN and cylinder lube oil feed rate
- Fuel and cylinder lube oil systems
- Summary

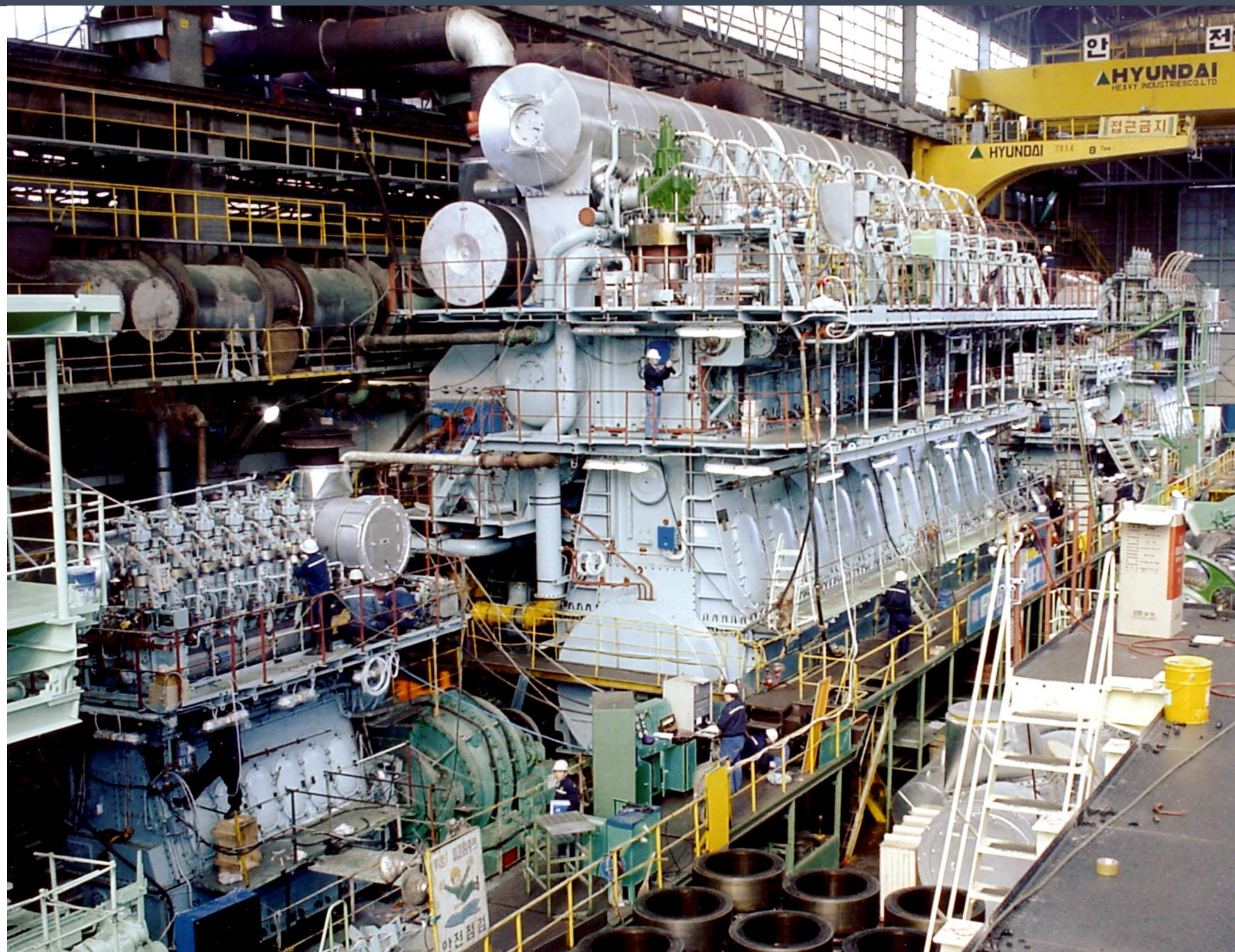
by Kjeld Aabo

Director, Customer Support

MAN B&W Diesel A/S

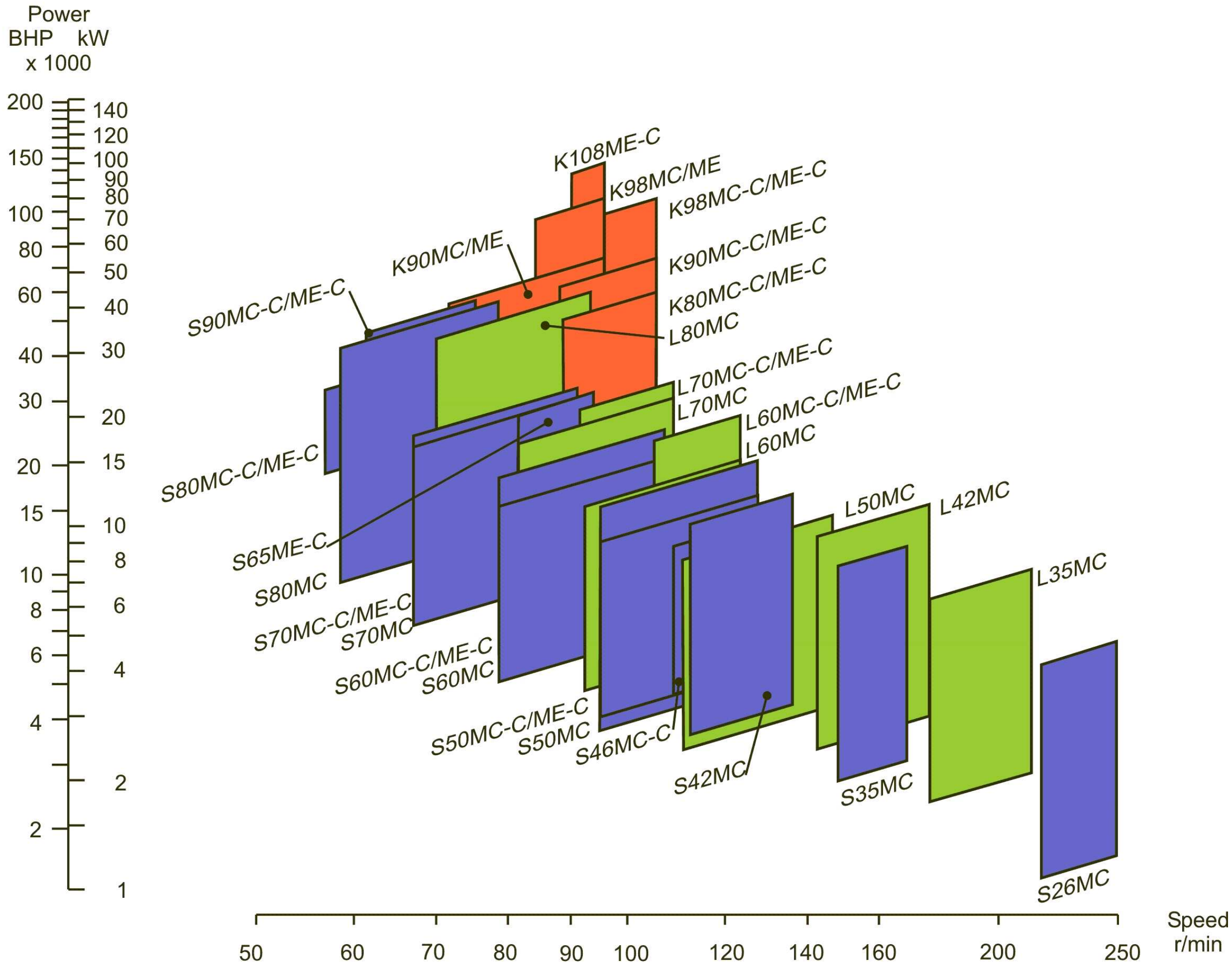
Chairman of CIMAC, Heavy Fuel Working Group

10K98MC-C and 6S35MC on the same Testbed



Marine Engine Programme 2005

Two-Stroke Propulsion



Proposals for IMO C3 Tier 2 Regulation

Component	EPA/IMO proposals	EUROMOT proposal
NOx	20 to 30% reduction	A fixed 2 g/kWh reduction
PM Fuel Sulfur	Tied to the HFO type and fuel S content	Not included
HC	Only VOC from storage tanks Exhaust HC not to increase EPA limit of 0.4 g/kWh is too tight	Not included – assumed low
CO	EPA limit of 3.0 g/kWh CO not to increase	Not included – assumed low
SOx	Based on fuel S content	Not included

Emission Control – Cost

	Reduction capability				First cost in % of engine price	Running cost index Tier 1 = 100
	NOx	CO	HC	PM		
Primary methods						
Engine adjustments	**10-15%**	👎	👎	👎	**0%/Small**	**102**
SL & Alpha lube	**-**	**-**	👍	👍	**0%/Small**	**101**
Water emulsion	**20-30%**	**-**	**-**	👎	**10-20% *)**	**101**
SAM	**40-50%**	👎	👎	👎	**20-30% *)**	**101**
Secondary methods						
SCR (Sel. Cat. Reduction)	**80-98%**	**?**	**?**	**?**	**50-70%**	**110**

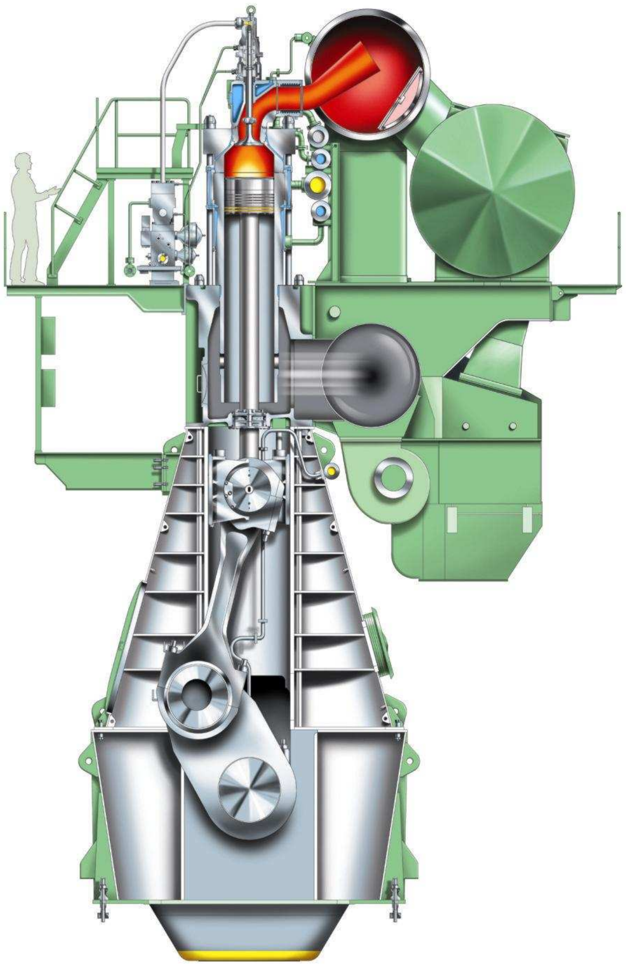
*) Depending on installation

Today's Fuel Oils

Marked demand to engine builders

- Safety
- Optimum engine layout
- High efficiency/low fuel consumption
- Low operation cost (MTBO)
- Reliability/availability
- Exhaust gas emission consideration

How to ensure good engine operating condition



- Monitoring and inspection before overhaul

  Check of
  - performance
  - cylinder condition

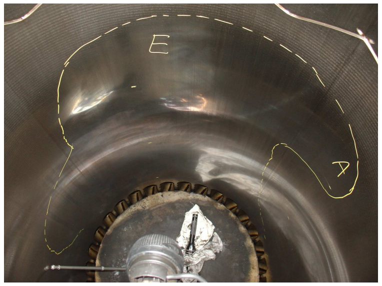
  (Turbocharger, cylinder condition, fuel equipment, exhaust gas system)

- Overhaul in case of irregularities only

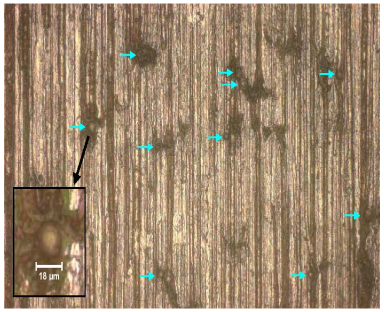
- No indication that fuel is the cause of engine operational problems when the engine condtion is good and the fuel treatment is working properly

External factors which influences engine condition

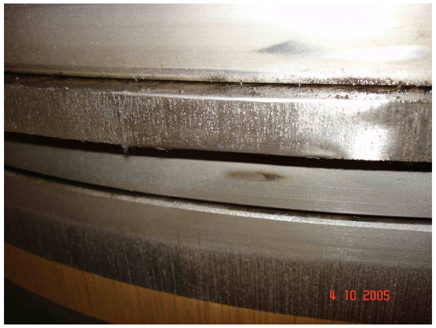
- Cylinder lube oil
  - Quality
  - Type (BN)
  - Dosage



- Fuel oil
  - Contaminants
  - Cat fines (treatment, purification)

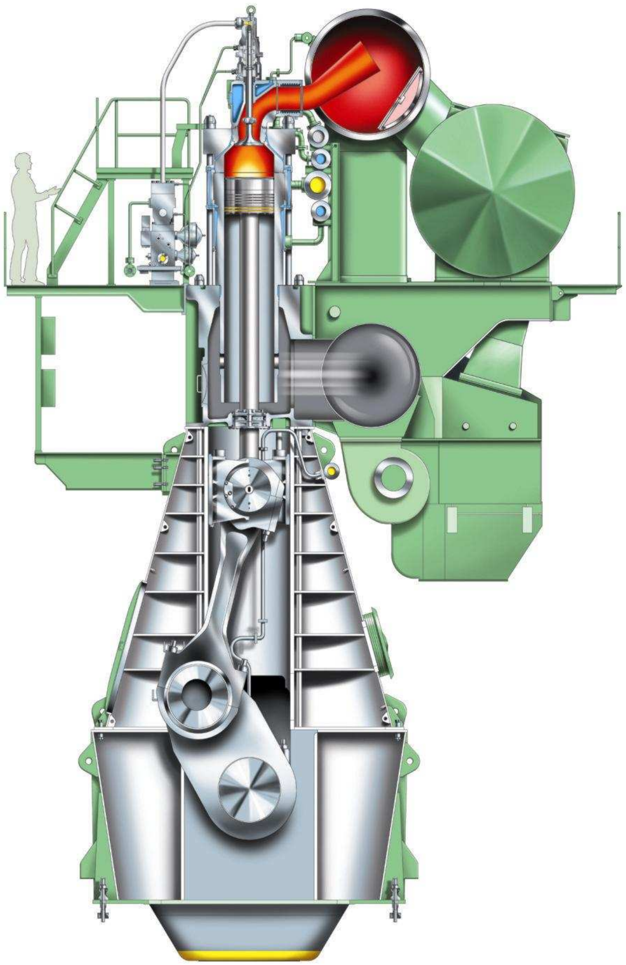


- Ambient condition
  - Humidity
  - Water mist catcher



- Exhaust gas boiler
  - Pressure drop in exhaust system

How to ensure good engine operating condition

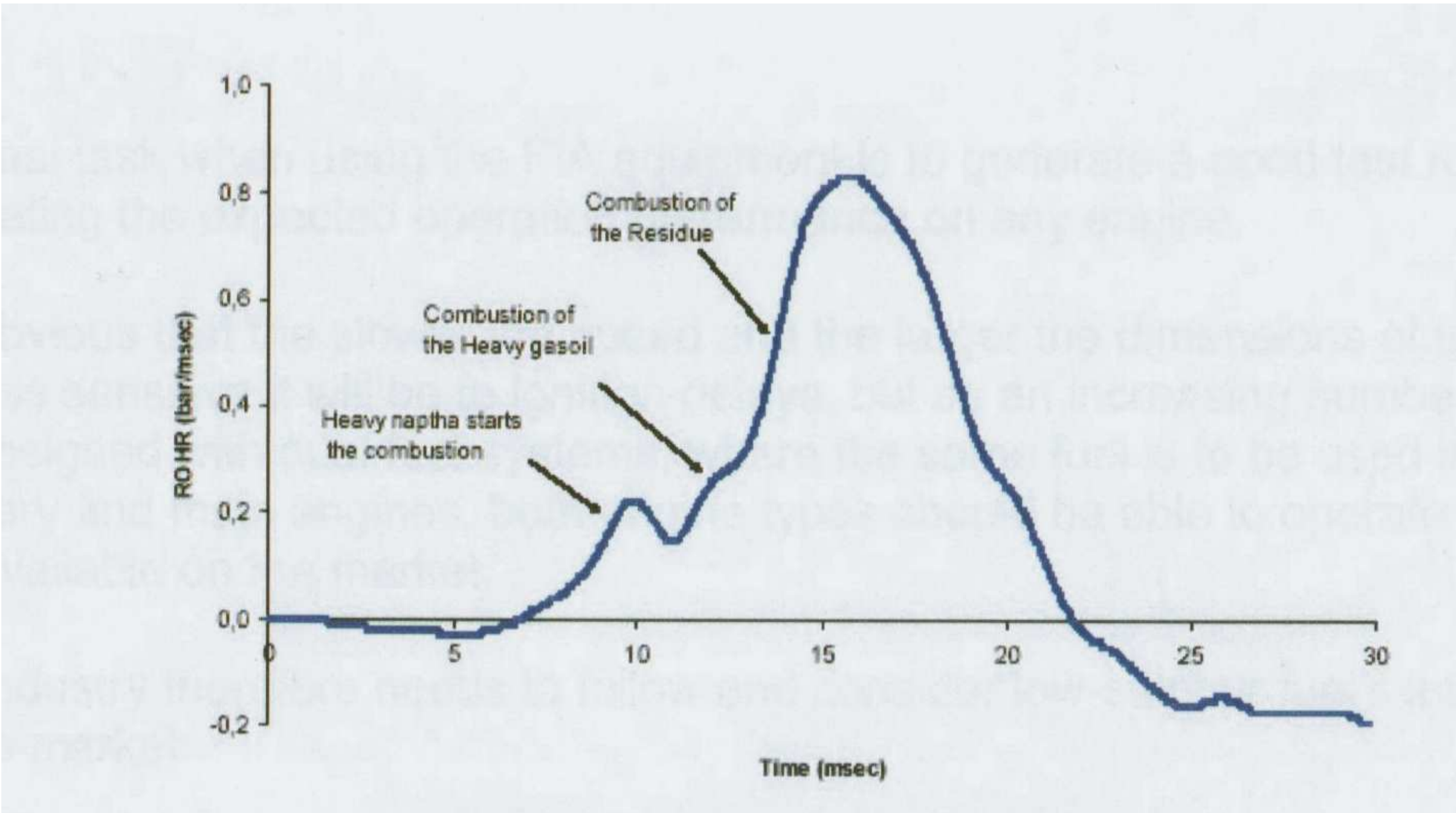


- Density - Centrifuges
- Viscosity - Preheating
- Flash point – Safety
- Pour point – Handling
- Carbon Residue – Fouling of gas ways
- Ash – Can be abrasive
- Vanadium and sodium – Corrosion and t/ch deposits
- Sulphur – Corrosion
- Water – Centrifuges
- Catalytic fines - Centrifuges
- Off-spec. Fuels – Natural gas, Bitumen, Orimulsion
- Bio fuel

Incompatibility of fuels

- When switching from HFO to a distillate fuel with low aromatic hydrocarbon there is a risk of incompatibility.
- The asphaltenes of the HFO are likely to precipitate as heavy sludge with clogging filters as result.
- Use of test compatibility kit on board or guarantee from fuel supplier that fuels used can be blended

ROHR (Rate of Heat Release) Curve



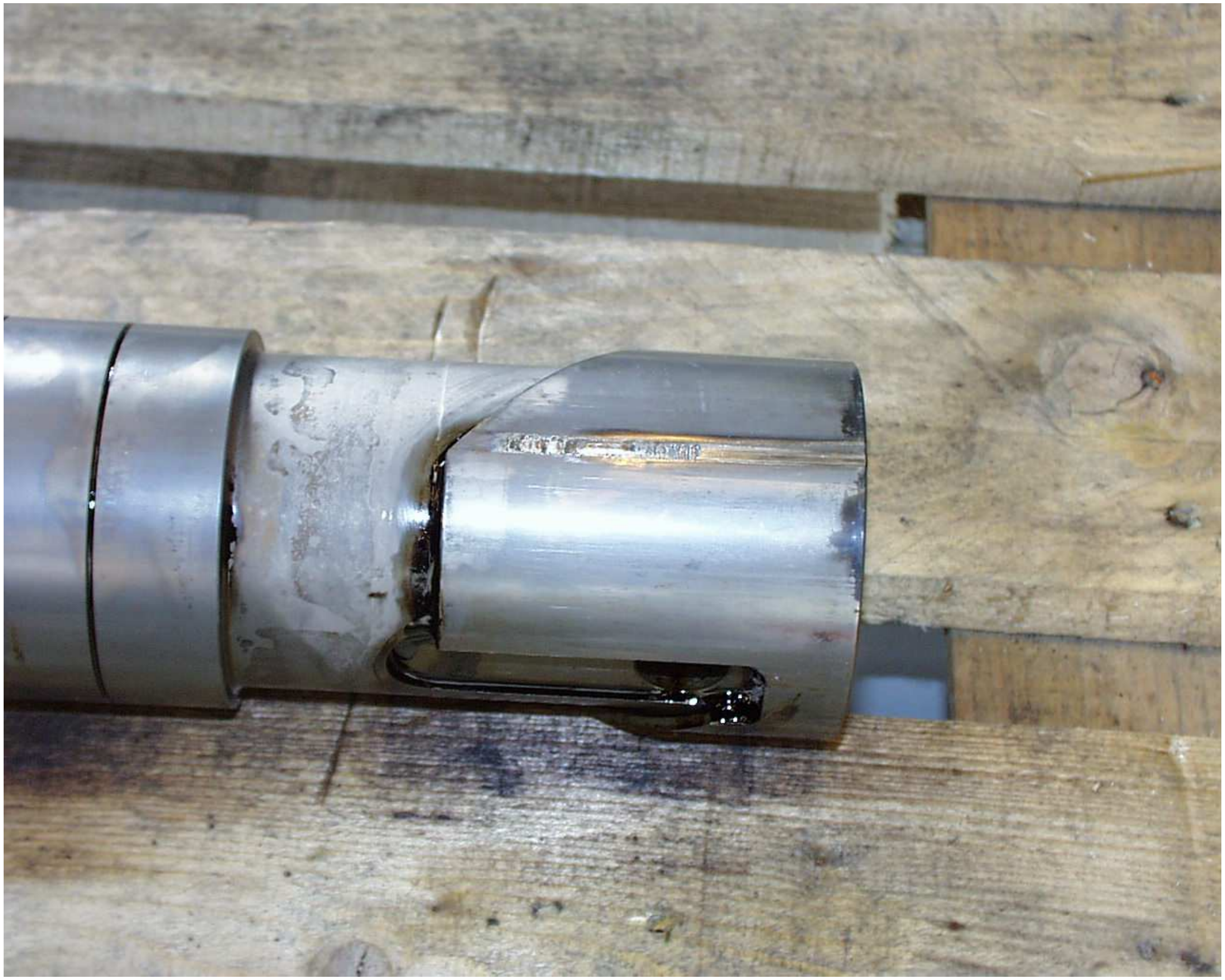
Low sulphur Fuels operation.

- Viscosity

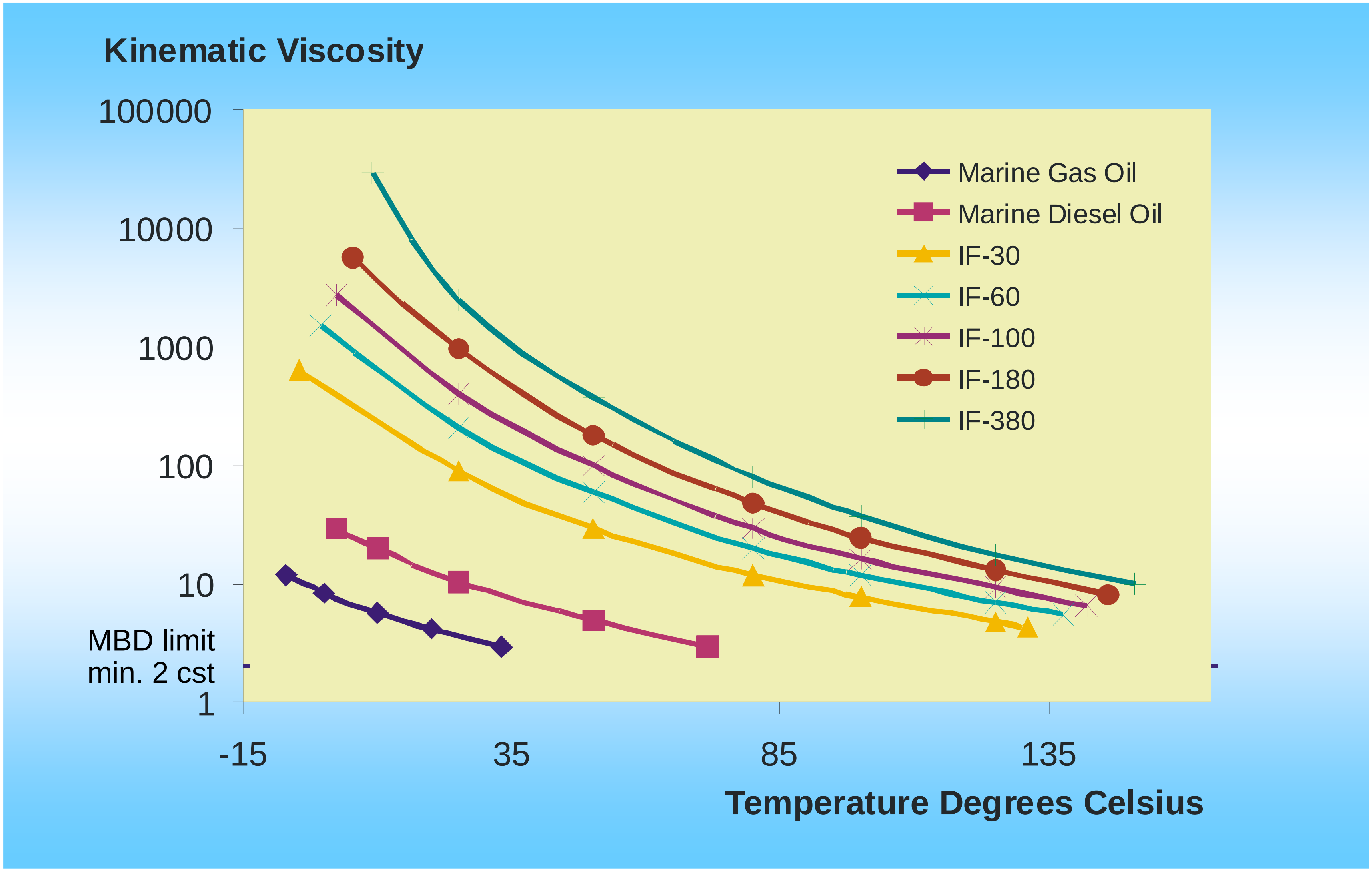
Use of DO and GO when low sulphur HFO is not available.

- The ”change over” procedure between fuels with different Viscosities.

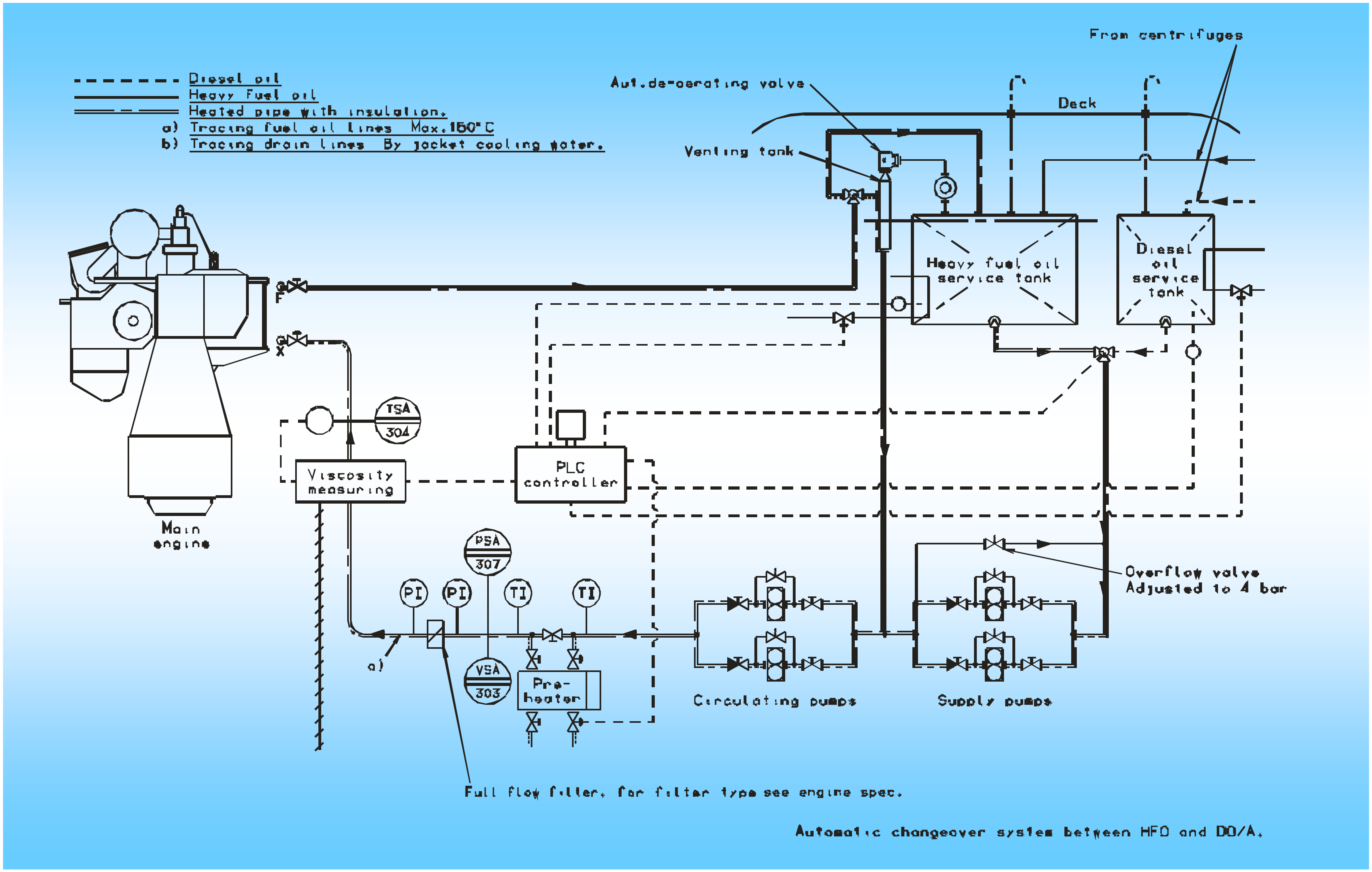
Damage to Fuel Pump Plunger



Marine Fuels



Fuel Oil System



Low sulphur Fuels seen on the marked today.

Tendency for the low sulphur fuels we see on the marked today

- To have lower ignition quality.

Can call for attention in connection with High and Medium speed engines.

- To have an increase in cat-fine level.

Calls for even higher attention on operation of fuel centrifuges

Methods for determination of fuel quality

FIA

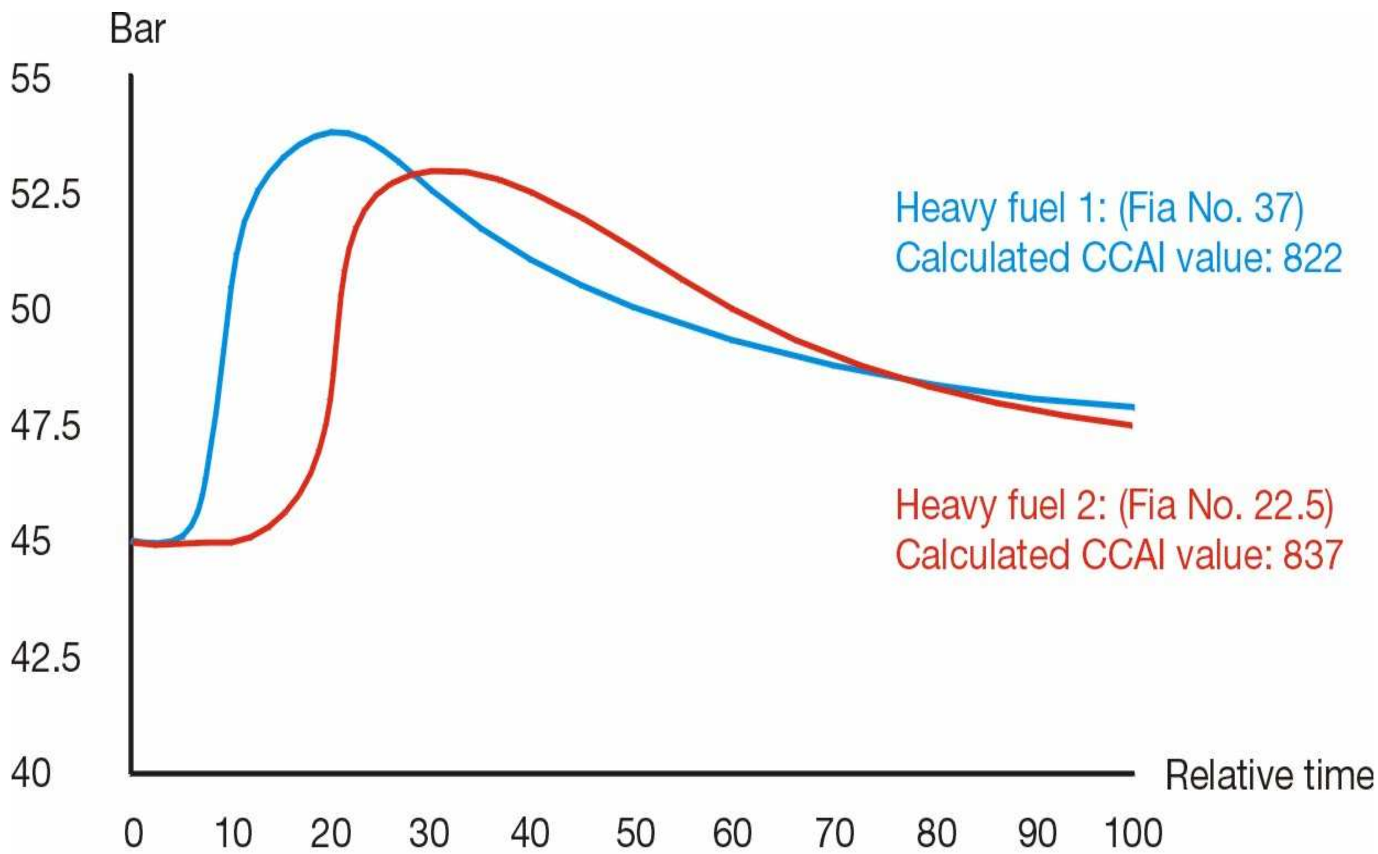
- Ignition delay
- Combustion quality (Rate of Heat Release ROHR)

CCAI / CII

- Calculation of fuel ignition quality by use of viscosity and density

MAN B&W Diesel

FIA results



Good fuel	≧ 25 Fiacn
Fuel which can give difficulties	≲ 25 Fiacn
Bad fuel	≦ 20 Fiacn

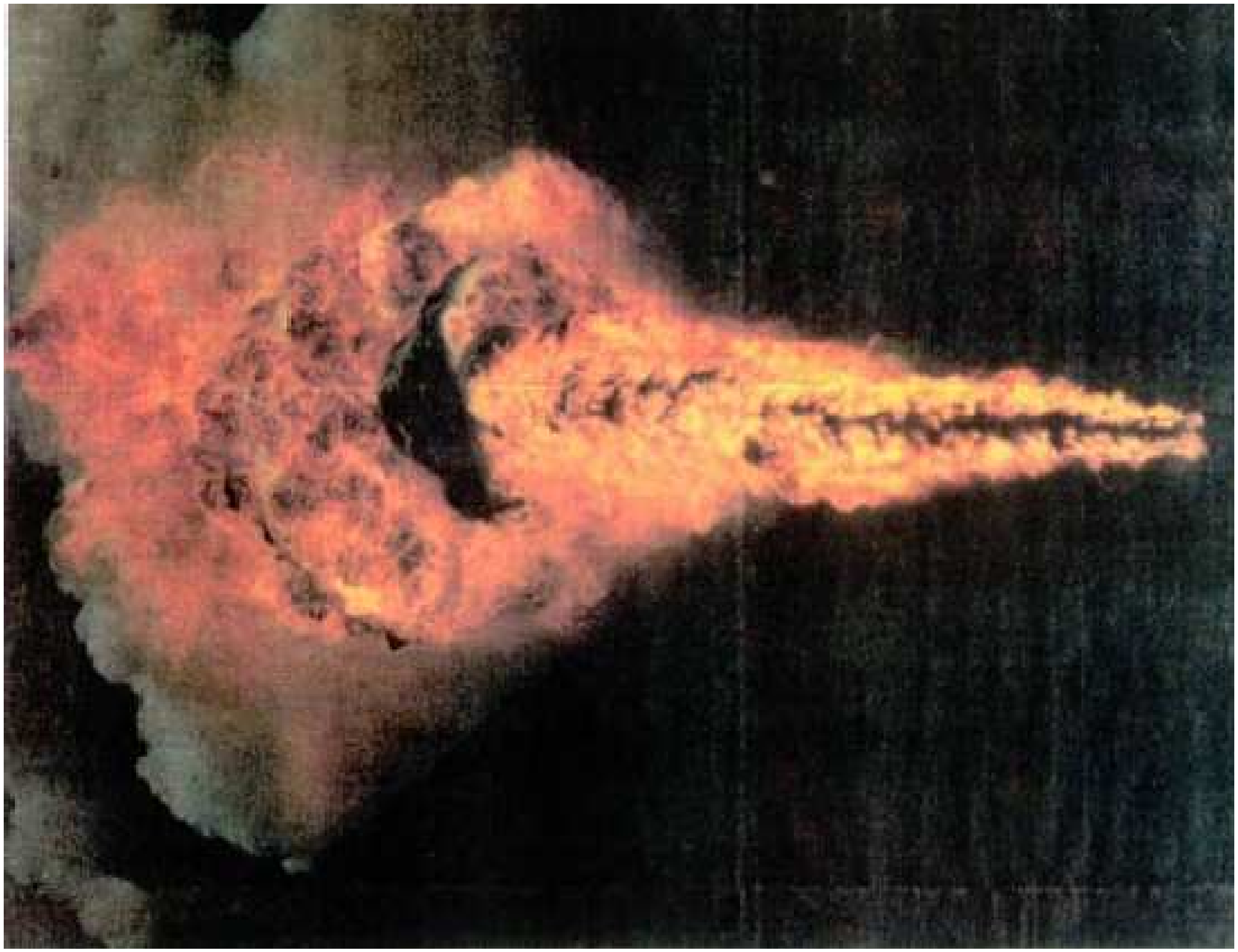
Ignition delay

- **Physical ignition delay**
  - Oil moving through the fuel valve
  - Injection

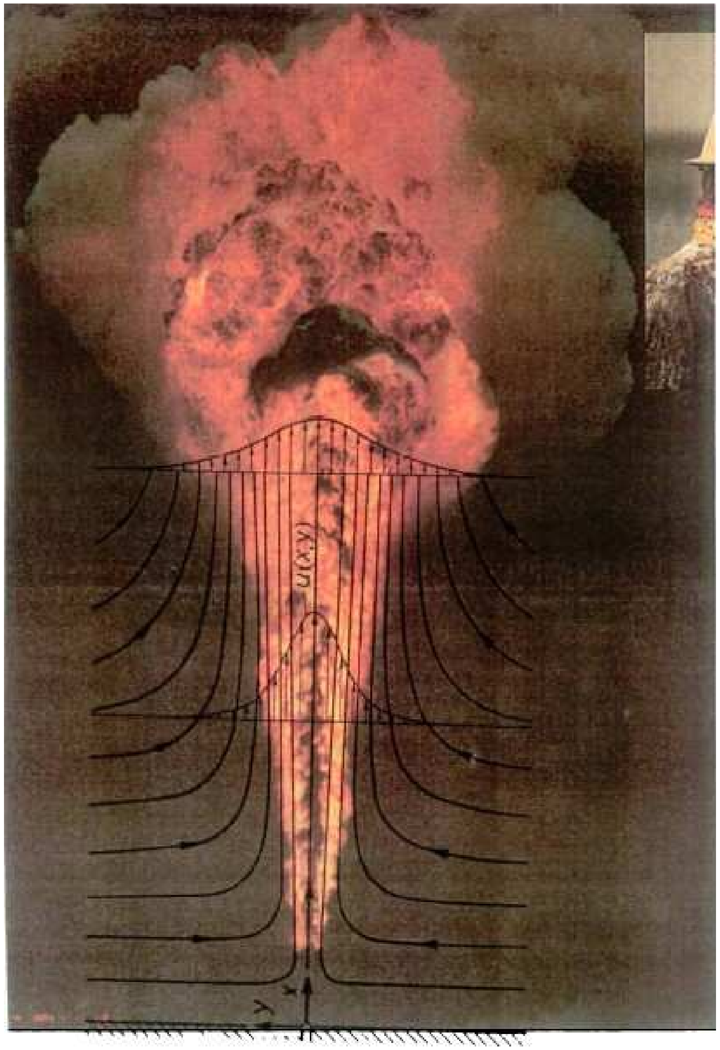
- **Chemical ignition delay**
  - Self ignition
  - Combustion starts

- **Physical ignition delay is 10 x chemical ignition delay**

Fuel jet



Fuel jet



MBD test of different fuels

Fuel No	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	Units
Viscosity	3.8	84	85	141	198	255	470	520	560	690	710	800	1200	50,000	-	cSt/50°C
Density	968	995	970	993	938	977	985	983	1,010	1,008	1,030	935	998	1,040	1.01	kg/m^3 at 15°C
Flash point	98	84	80	103	100	106	90	95	90	79	84	>40	80	>60	>70	°C
Conradson Carbon	0.3	17.2	12.1	13.3	9.4	14.5	16.8	14.8	17.3	22.1	24.7	9.4	14,1	24.2	11.7	% weight
Asphalt	0.78	15.1	8.9	9.2	3.7	10.0	11.3	12.8	14.6	19.3	29.0	1.02	12	-	-	% weight
Sulphur	0.10	2.72	1.16	0.91	0.83	0.87	0.90	1.18	2.22	3.52	3.30	0.37	4	4.8	2.8	% weight
Water	0.01	0.01	0.01	0.00	0.01	0.02	0.02	0.01	0.00	0.00	0.00	-	0,65	0.05	-	% weight
Ash	0.00	0.065	0.025	0.03	0.03	0.025	0.03	0.035	0.04	0.07	0.09	0.043	-	0.035	0.18	% weight
Aluminium	-	-	-	-	-	-	-	-	-	-	-	-	12	2.0	1	mg/kg
Vanadium	0	220	20	23	12	17	24	45	122	300	370	415	312	149	-	mg/kg
Sodium	0	27	23	24	25	40	35	22	22	24	50	9	-	-	-	mg/kg
CCAI	912	874	849	866	807	843	844	841	868	864	885	-	-	-	-	-

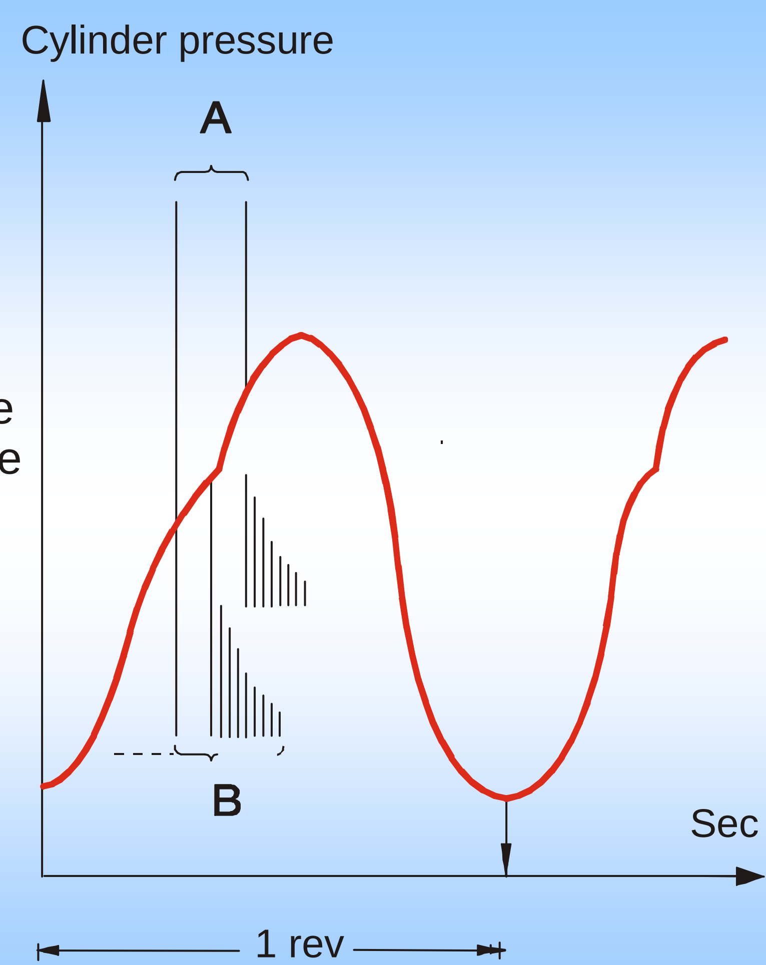
Fuel Acceptance

Low speed (two-stroke)
60/103.4 = 0.58 sec/rev

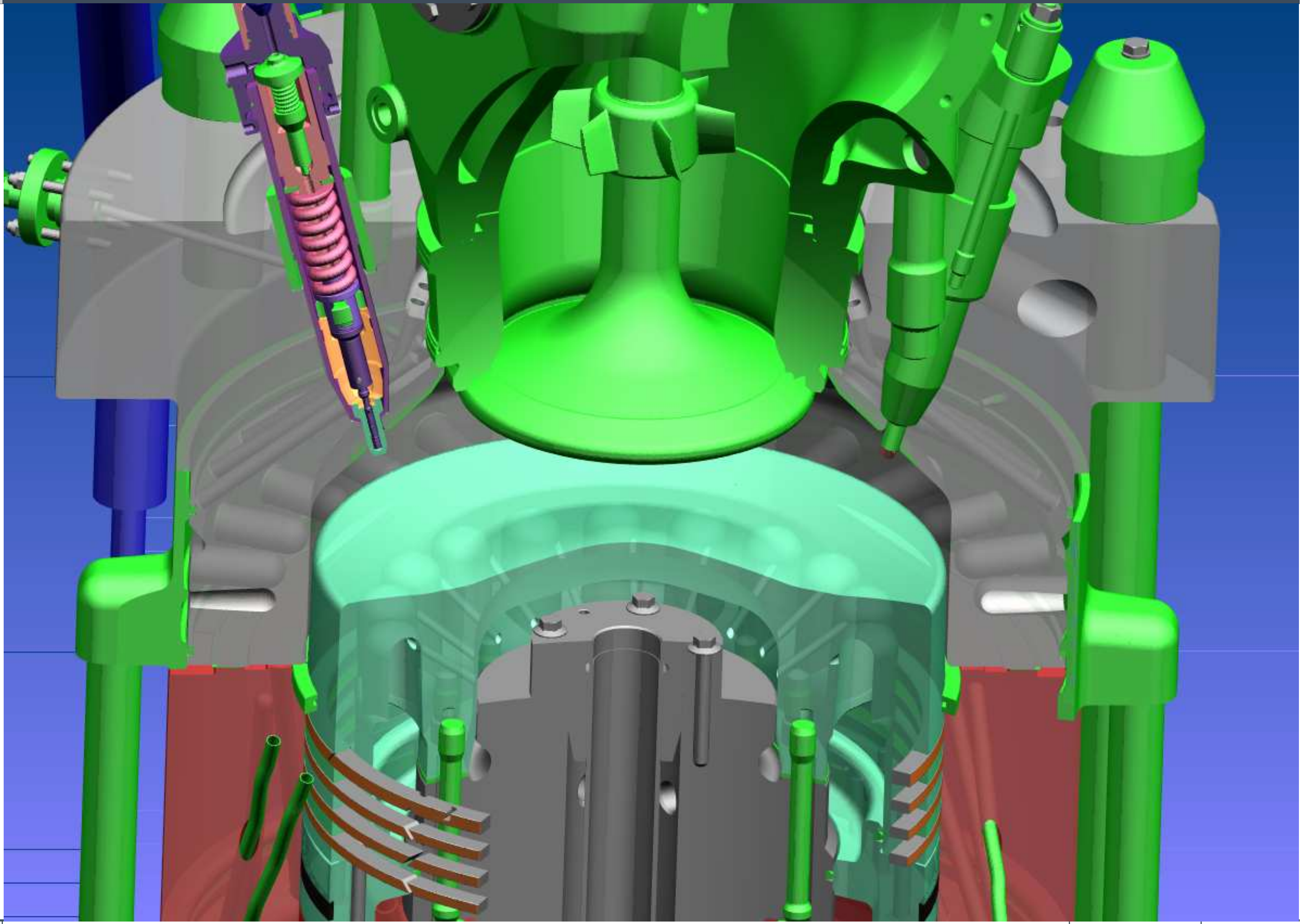
Medium speed (four-stroke)
60/600 = 0.10 sec/rev

A: Fuel injection period
(~22 deg. crankshaft) ~35 msec for two-stroke
~ 9 msec for four-stroke

B: Possible max ignition delay
~20 msec for two-stroke and four-stroke
In medium speed engines all fuel can be injected before ignition i.e. detonation may occur if delay due to fuel quality is large.



Optimising the Cylinder Condition when operating on low sulphur fuels



Chemical Conversion of S to H_2SO_4

$$S \xrightarrow{[0_2]} SO_2 \xrightarrow{[0]} SO_3 \xleftrightarrow{[H_20]} H_2SO_4$$

Fast	Slower	Equilibrium
100% Conversion	0.3 - 7% Conversion	Pressure & Temp. Dependent

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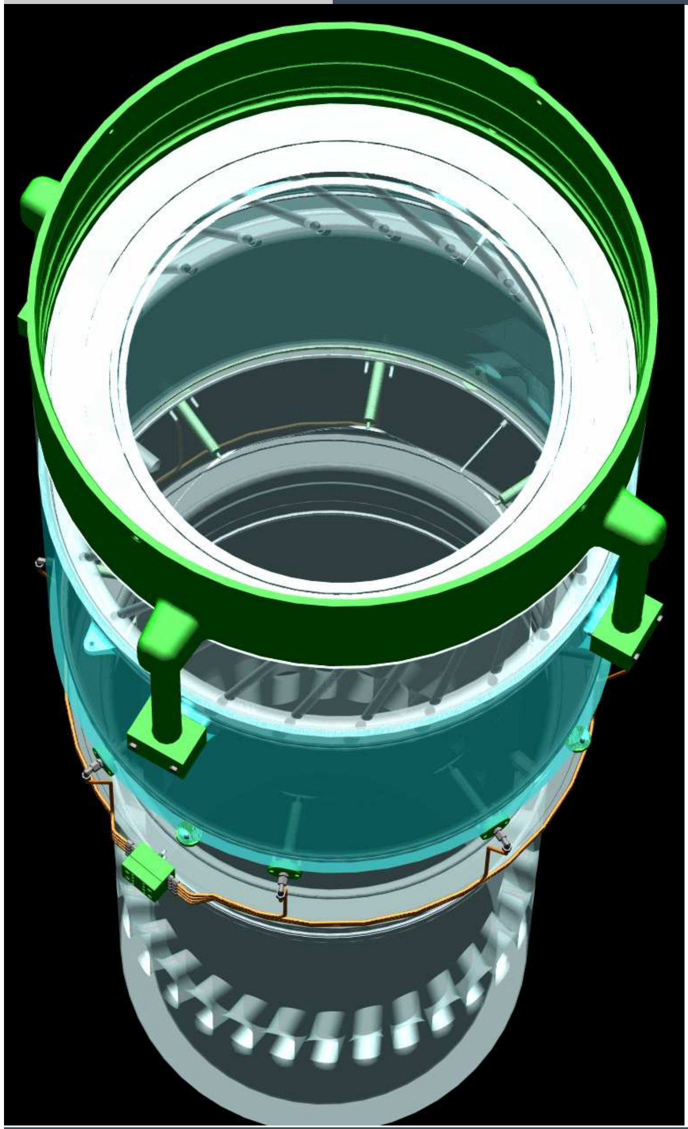
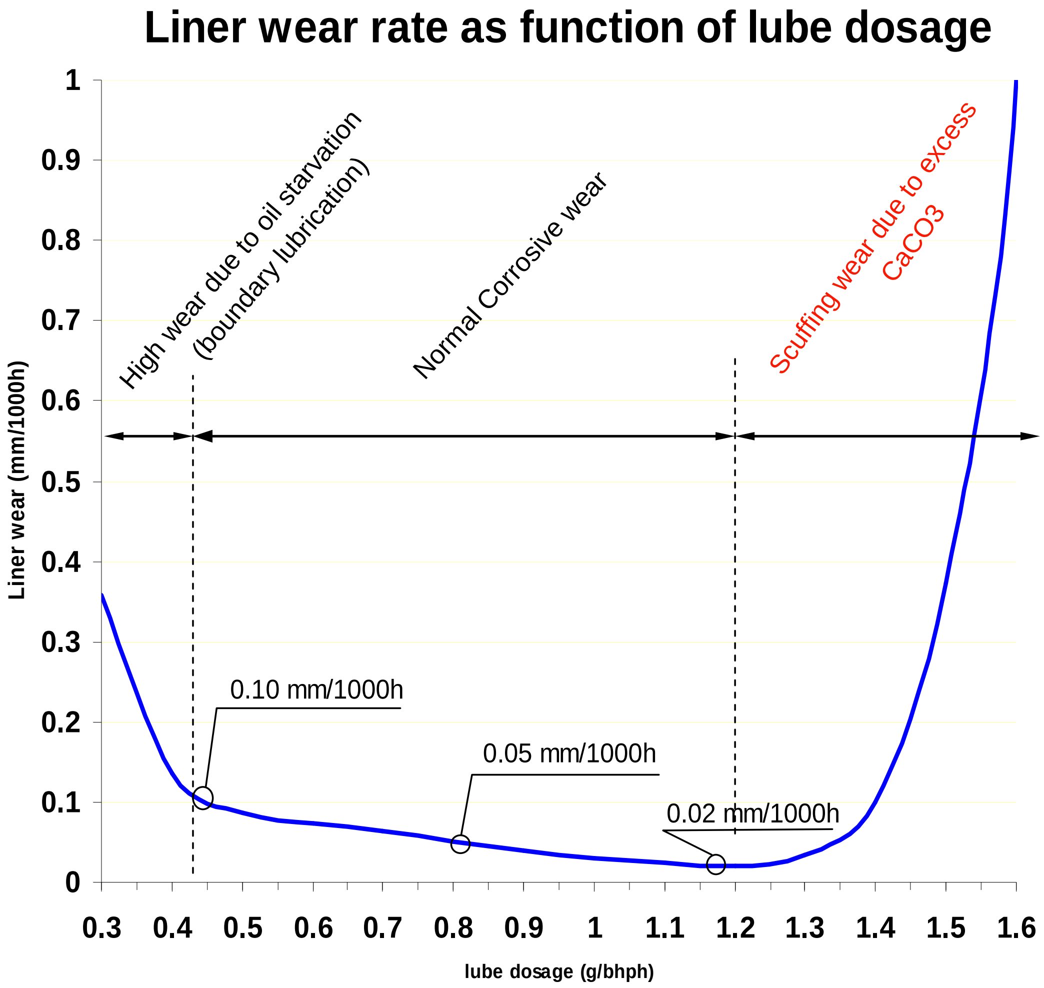
Optimising the Cylinder Condition Lubrication versus Maintenance





Cylinder condition

- Piston crown with deposits

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Cylinder Liner Surface

‘Open’ graphite structure with good tribological abilities

1.6 mm

‘Closed’ graphite structure with reduced tribological abilities

1.6 mm

Experience and Case Stories of Low-sulphur Fuel Oil Operation

- **Too little corrosion may result in too little wear and in damaging polishing of the liner surface**
- **A BN 70 can therefore be a less optimal solution than a BN 50 cylinder lube oil**
- **But a BN50 oil will also have to be designed for the purpose**
- **Too High Calcium Carbonate amount =**

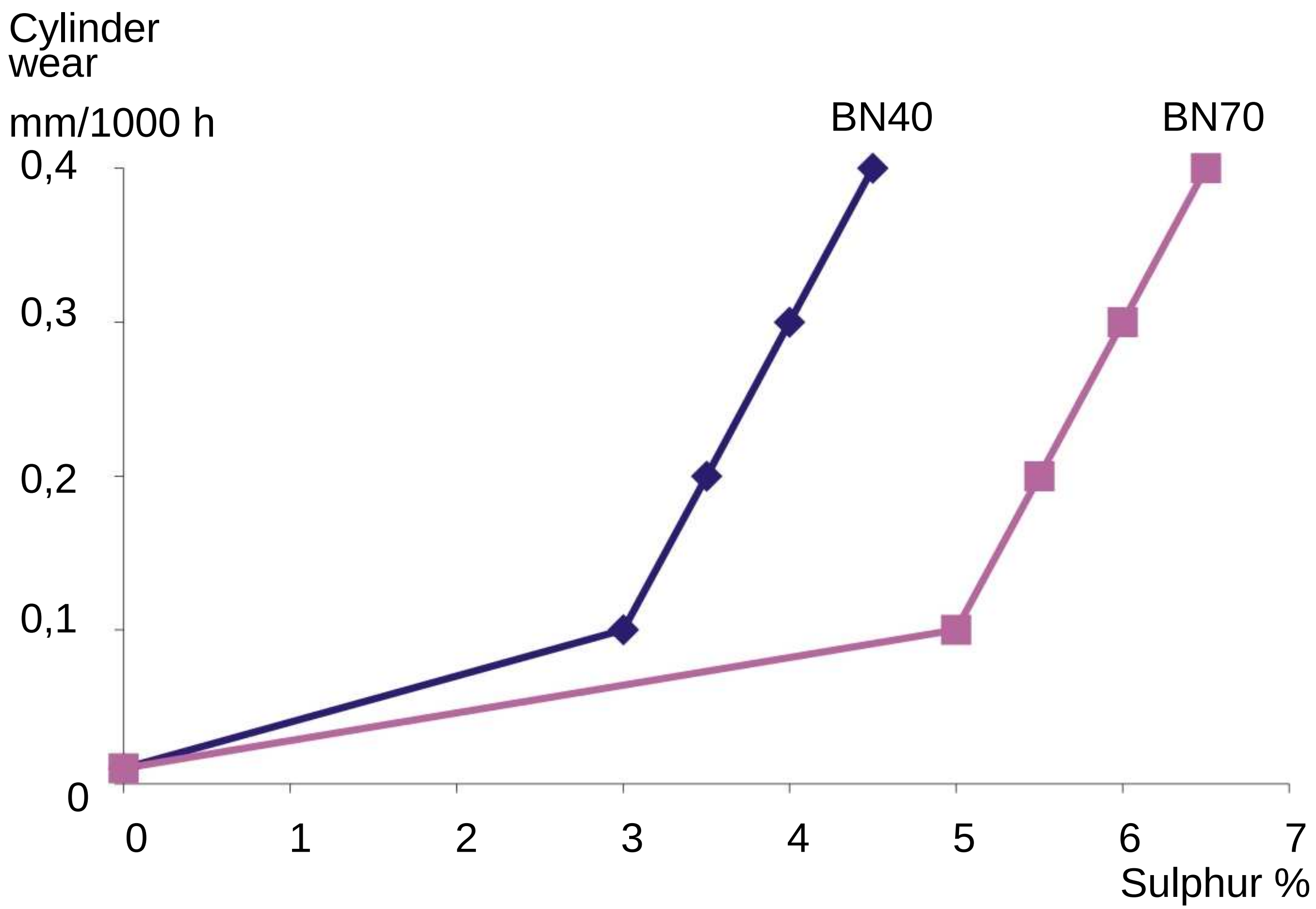
  Chemical bore polish

  Mechanical bore polish

MAN B&W Diesel

Comparison of Sulphur Content and Lube Oil TBN

With Respect to Cylinder Wear. Equal Cylinder Oil Feed Rates



Case story 1

Ship operation

Test time of BN50	14,500 service hours
Ship type	Car carrier
Engine type	8S60MC
Fuel type	MDO max. 1% sulphur
Cylinder oil feed rate	0.95 g/BHPh
Original cylinder lube oil	BN 70
Tested cylinder lube oil	BN 50

Experience

The overall cylinder condition was satisfactory. There was good gas sealing and mostly smooth and round rings. Some liners still have light remains of machining marks on the running surface.

The most stable situation with regard to micro-seizures was found on the TBN 50 lubricated units.

The Taro special 50 oil has a less efficient cleaning ability, but a better matched sulphur acid neutralisation effect.

Max. wear rate is 0.014 mm/1,000 hours.

Case Story 2

- Engine type Various S35MC engines
- Fuel type MDO sulphur content below 0.2%
- Cylinder oil feed rate Over-lubrication in accordance with the breaking-in programme
- Normal running-in time at MAN B&W Diesel A/S, Alpha Diesel, is 50 hours
- (more than normal)

MAN B&W Diesel

Condition After 17 Hours on Low-Sulphur Distillate Fuel with BN70 Commercial Lube Oil

Experience with Tested Oils

Running-in test.
Failed 40BN candidate

Running-in test
Failed 40BN candidate

Running-in test
Promising candidate

Case story 3

- Engine type 4 x 12K90MC-S
- Fuel type High viscosity HFO with a sulphur content of 0.2-1.0%
- Cylinder oil feed rate Currently at 0.85 g/BHPh

- The plant entered operation in November 1998 and suffered from cylinder liner scuffing shortly after starting

- After the introduction of a BN 40 oil in August 2000, the liner and ring started to heal themselves and no more scuffing incidents occurred

Lubricating oils					
	Low speed main engines			Auxiliary engines L23/30 & L28/32	Auxiliary engines L16/24, L21/31 & L27/38
Type	Circulating oil	Cylinder oil		Circulating oil	Circulating oil
Requirement	SAE30/BN 5-10	SAE50/BN 70-80	SAE50/BN 40-50	SAE30/BN 20-25	SAE40/BN 20-40
Oil company					
BP	OE-HT 30	CLO-50M	CL/CL-DX 405	IC-HFX 203	IC-HFX 204/304/404
Castrol	CDX 30	Cyltech 70	Cyltech 40SX/40S	TLX 203	TLX 204/304/404
Chevron	Veritas 800 Marine 30	Delo Cyloil Special	Taro Special 50	Delo 2000 Marine 30	Delo 3400 Marine 40
Total	Atlanta Marine D3005	Talusia HR 70	Talusia LS 40	Aurella 3020	Aurella 4020 – 4030
Exxon	Exxmar XA	Exxmar X70	Mobilgard L540	Exxmar 24 TP30	Exxmar 30 TP40
Mobil	Mobilgard 300	Mobilgard 570	Mobilgard L540	Mobilgard (TB 25)	Mobilgard M430-M440
Shell	Melina 30/30S	Alexia 50	Alexia LS	Argina oil S30	Argina oil S40
Texaco	Doro AR30	Taro Special HT70	Taro Special 50	Taro 20 DP 30	Taro 20 DP 40, 30 DP 40

Use of BN40 Cylinder oil feed rates
Low S fuel, Alpha ACC

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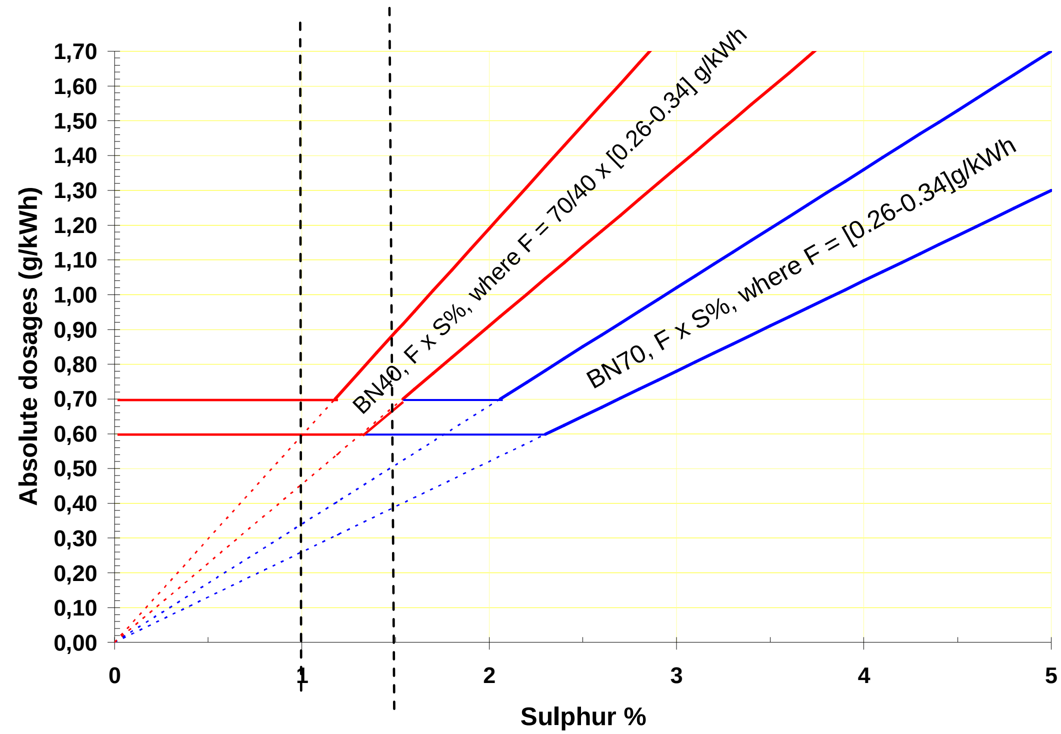
The correlation between fuel sulphur level and cylinder oil can be shown as follows:

Fuel sulphur level <1%: BN40/50 recommended

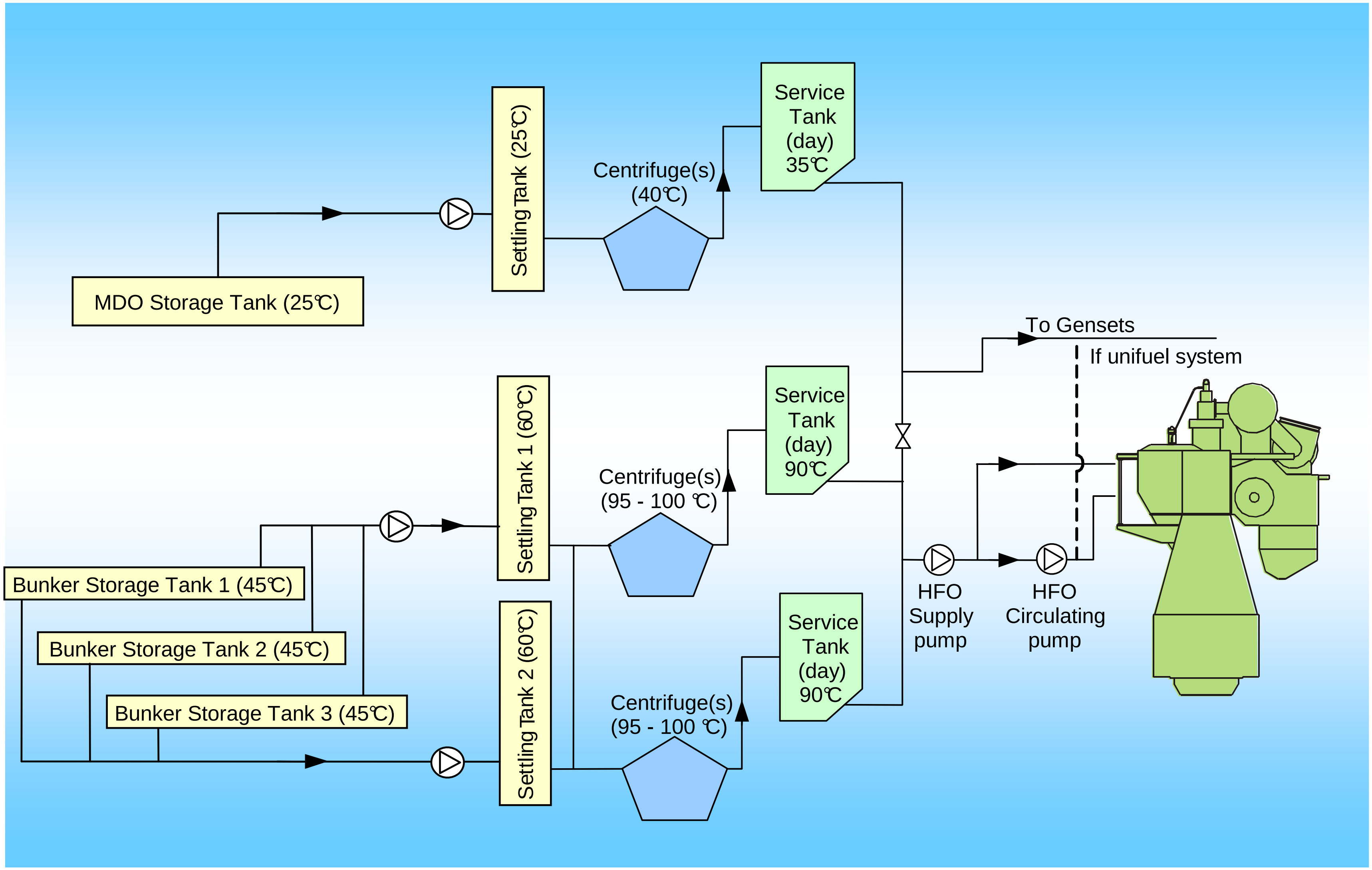
Changeover from BN70 to BN40/50 only when operating for more than one week on <1% sulphur

Fuel sulphur level 1-1.5%: BN40/50 and BN70 can be used

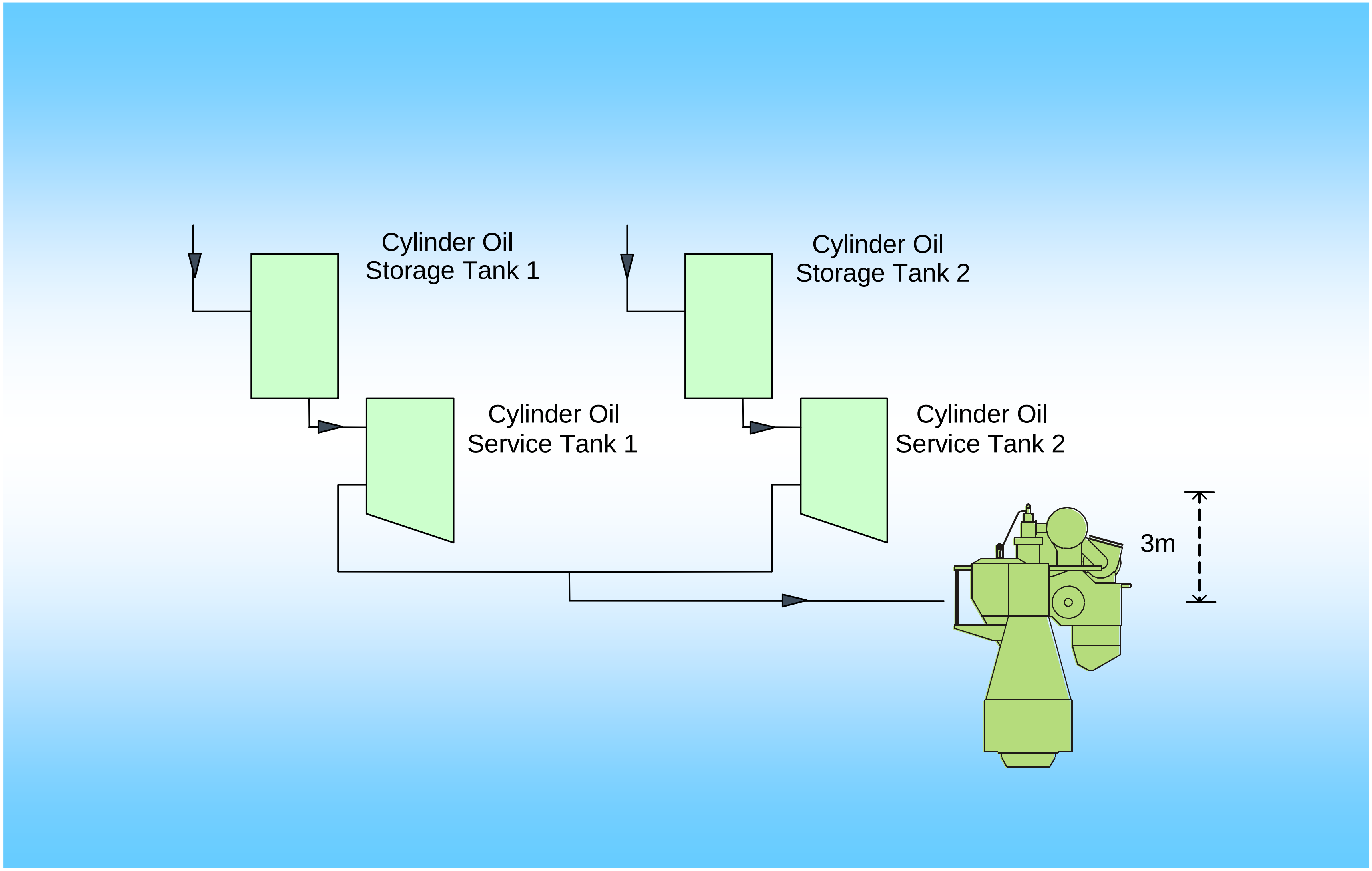
Fuel sulphur level >1.5%: BN70 is recommended



One MDO Settling Tank and Two Sets of HFO Settling and Service Tanks



Two Independent Cylinder Oil Systems



Summary

1. Exhaust gas from marine engines will be further regulated
2. When exhaust gas scrubber technique is finally tested and introduced, there will still be many ships on low sulphur fuel
3. No difference in performance of engines between low sulphur fuel, DO/GO and HFO
4. However, necessary precautions have to be taken by operators
5. Marine Industry has to follow carefully the development of low sulphur fuel oils to ensure proper quality

Scrubber Performance Objectives

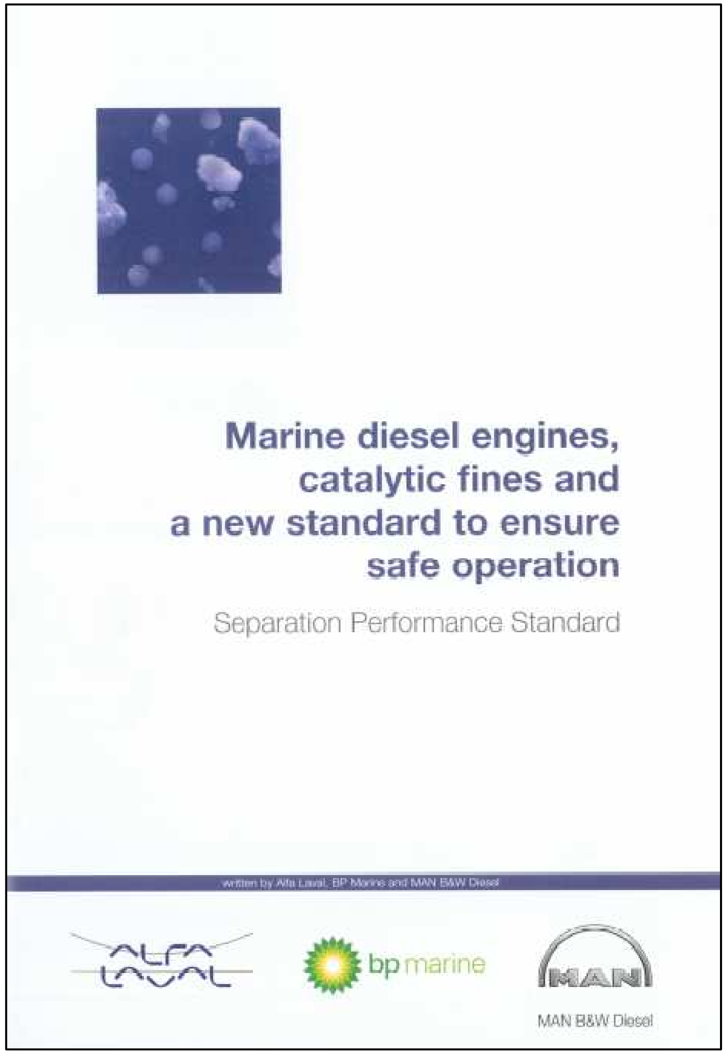
- SOx reduction > 95%
- NOx reduction ~10%
- Particulate reduction ~ 80%
- Exhaust noise attenuation
- No measurable impact to sea water condition

- We need to see it commercial available

First commercial scrubber installation

mv Pride of Kent project

BP Seminar
13 March 2006



BP Seminar
13 March 2006

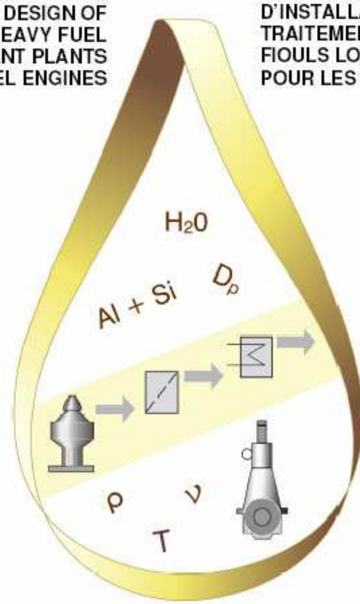
CONSEIL INTERNATIONAL DES MACHINES A COMBUSTION

CIMAC

INTERNATIONAL COUNCIL ON COMBUSTION ENGINES

RECOMMENDATIONS CONCERNING THE DESIGN OF HEAVY FUEL TREATMENT PLANTS FOR DIESEL ENGINES

RECOMMANDATIONS CONCERNANT LES PROJETS D'INSTALLATIONS DE TRAITEMENT DES FIOULS LOURDS POUR LES MOTEURS DIESEL



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